

12.812 The General Circulation of the Atmosphere and Climate Change

Course description:

Describes the general circulation of Earth's atmosphere and its maintenance. Second half of the course explores the response of the general circulation to climate change.

Instructor:

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Questions: Drop by, email, and office hour

Logistics

Course Webpage

pog.mit.edu/812.html

Class times

Tuesday and Thursday 2-3:30pm (but only once a week in part 2)

Classroom

54-824

Prerequisite

12.810 or instructors permission

Structure

Part 1: Lectures

The general circulation, its variability and maintenance.

Part 2: Readings and discussion

Use what we learned in Part 1 to discuss the response of the general circulation to climate change. We will read 1-2 papers a week.

Topics

Part 1: Lectures

Data sources and space-time decomposition, mean state and circulation (including the hydrological cycle), energetics, angular momentum and the transformed Eulerian mean, momentum flux cospectrum and Rossby wave chromatography, low-frequency variability.

Part 2: Readings and discussion

Possible topics include the effect of climate change on storm track intensity, jet position, superrotation and the MJO, the Walker cell, stationary waves, the pole-to-equator temperature difference and poleward energy flux, relative humidity and the hydrological cycle, and the effect of sea-ice loss on the midlatitudes.

Assessment

Grading:

Part 1: Problem sets (3 in total, 50%)

Part 2: Participation in class discussion. A student leads the discussion each week and writes a summary (~3 pages). Students answer short online questions on the reading prior to the class. (50%)

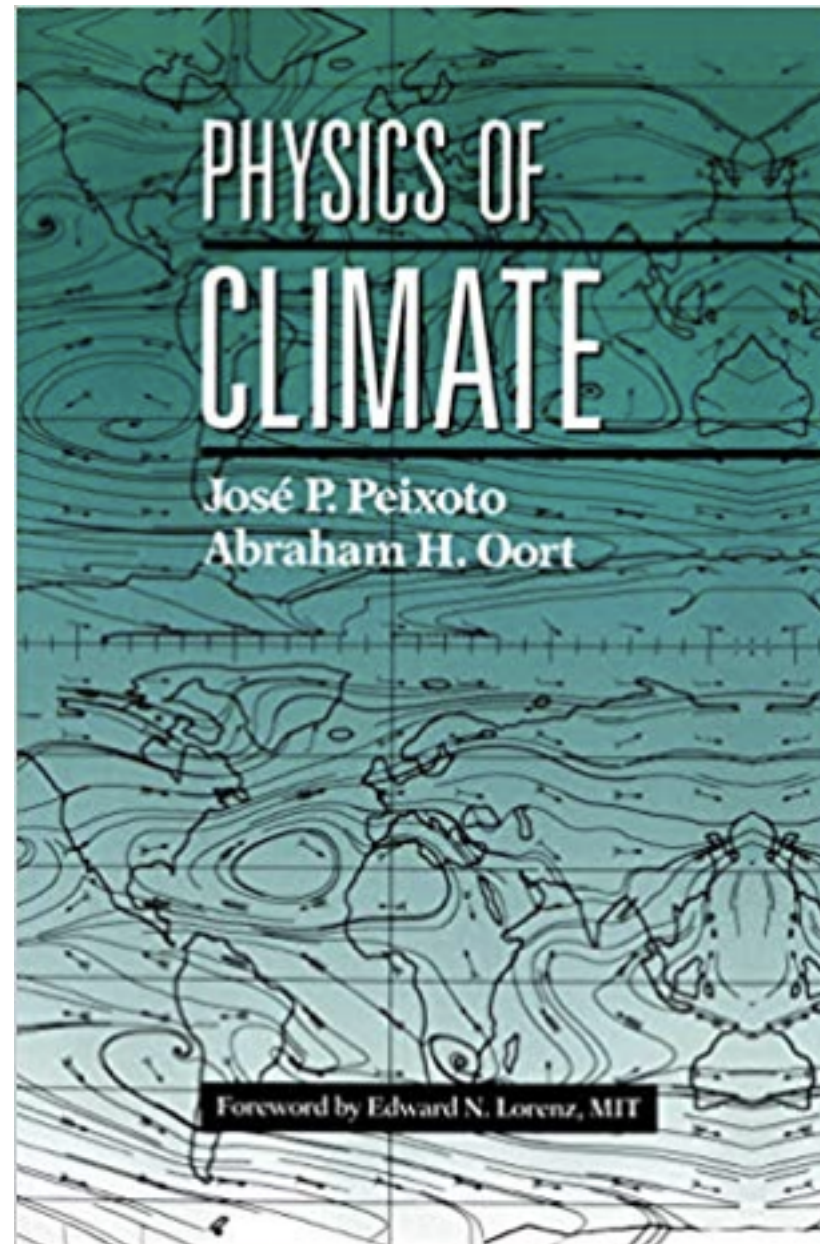
Problem Set Policy:

Collaboration is allowed, but students must write up the problem set on their own.

Textbooks and other resources

Primary Textbook

Physics of Climate, Peixoto and Oort



Textbooks and other resources

Secondary Textbooks

Atmospheric and Oceanic Fluid Dynamics, Vallis (2nd edition)

An Introduction to Dynamic Meteorology, Holton and Hakim (5th edition)

Review Papers

The general circulation of the atmosphere, T. Schneider,
Annu. Rev. Earth Planet. Sc., 2006

Response of the large-scale structure of the atmosphere to global warming, Vallis et al, QJRMS, 2015

Textbooks and other resources

Other resources:

Interactive plotting website:

<http://www.esrl.noaa.gov/psd/cgi-bin/data/composites/printpage.pl>

Gridded datasets:

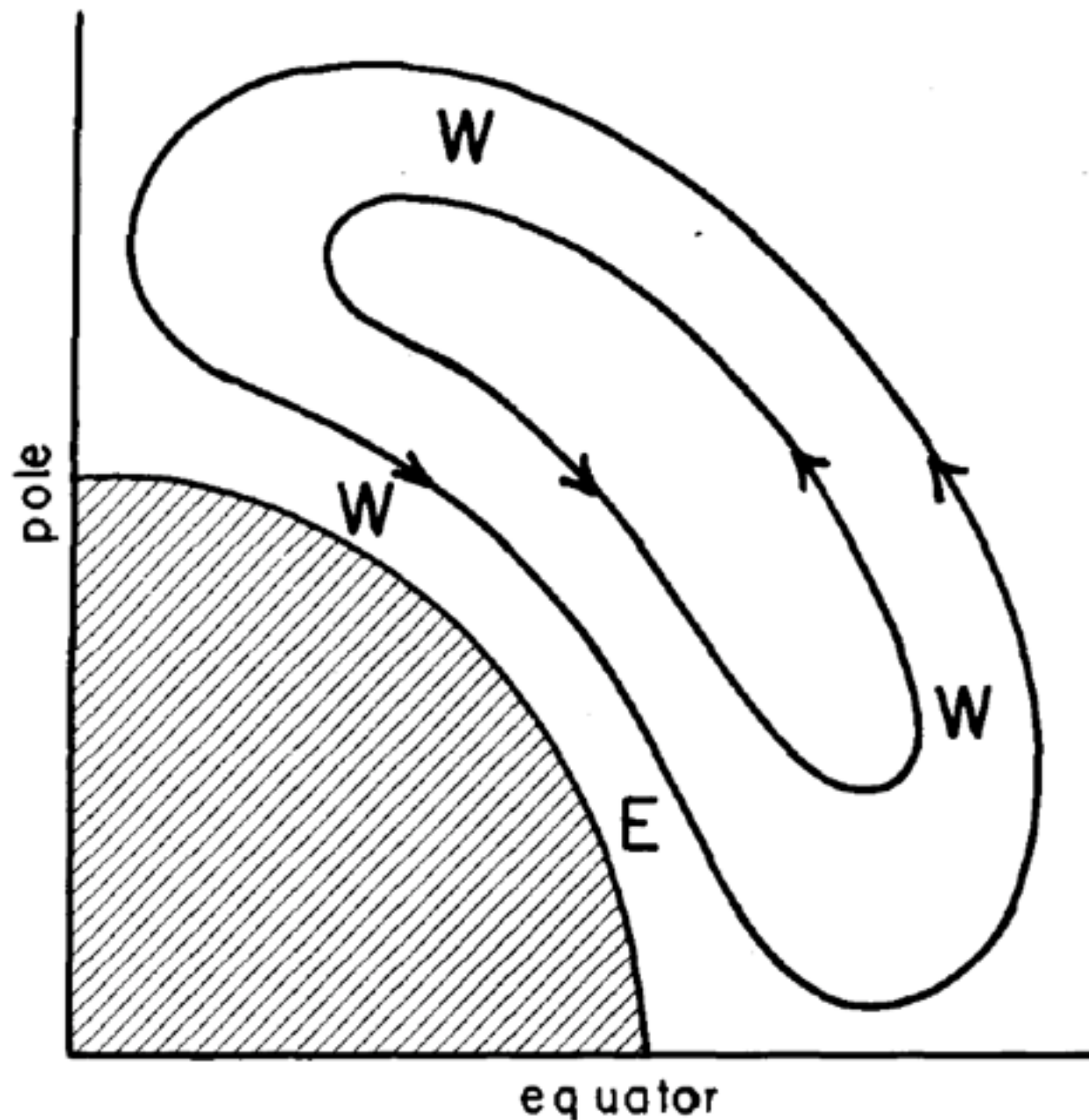
www.cdc.noaa.gov/data/gridded/

The general circulation: a historical perspective

During the past three centuries, the prevailing ideas about the general circulation of the earth's atmosphere have evolved in a stepwise manner. Early in each step, a new theoretical idea is formulated. Late in each step, the idea gains general acceptance, but, more or less concurrently, new observations show that the idea is wrong.

Lorenz, 1983

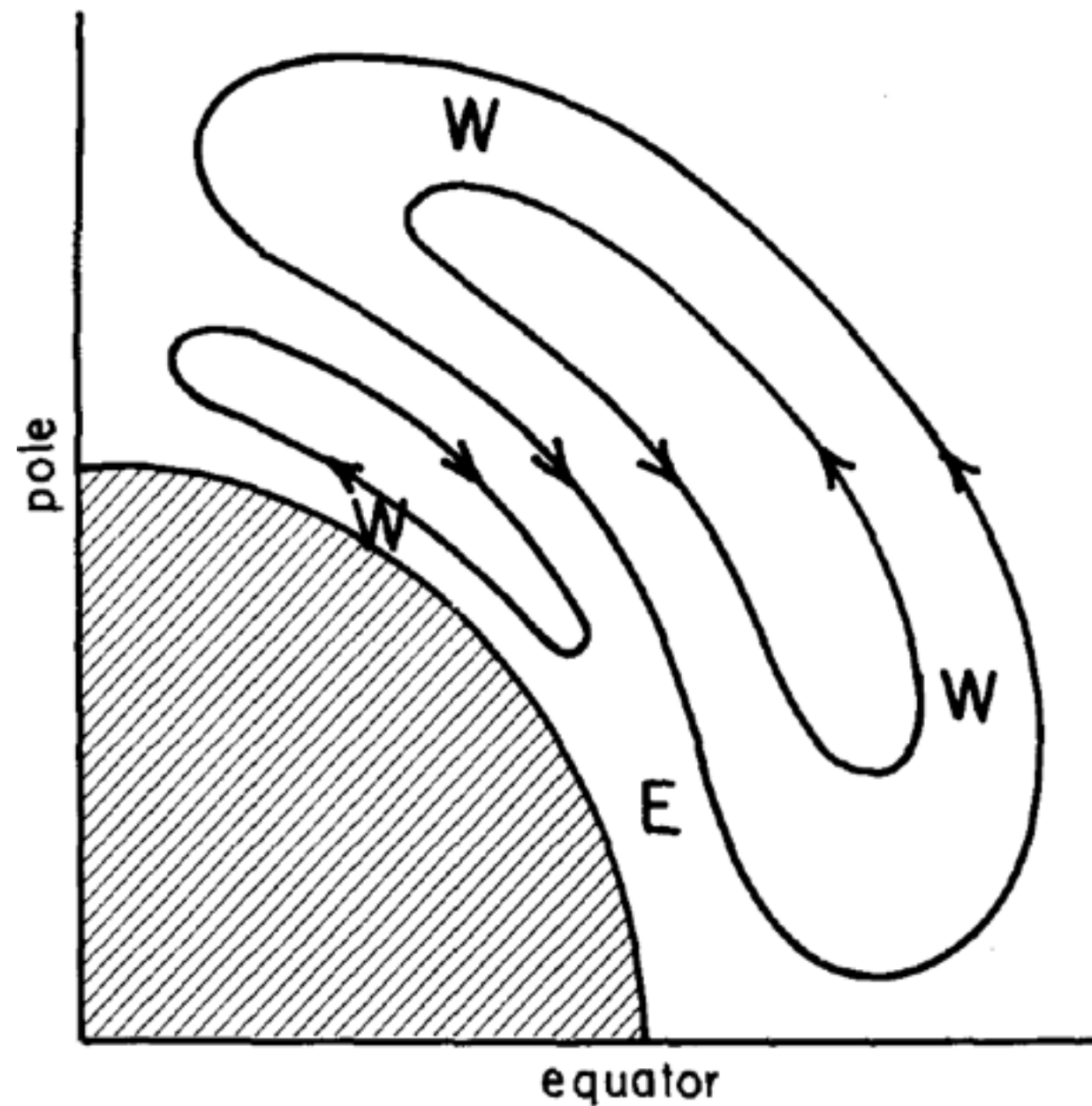
I) The general circulation: 1735 (Hadley)



- Zonal Coriolis force
- Surface E and W winds
- Angular momentum balance

... but surface poleward drift in midlatitudes!

2) The general circulation: 1857 (Thompson)



- Meridional Coriolis force
- Indirect cell
- Also Ferrel 1859

... but 1900 cloud study shows no upper level poleward flow in extratropics!

E. N. Lorenz, BAMS, Vol 64, 730-734, 1983

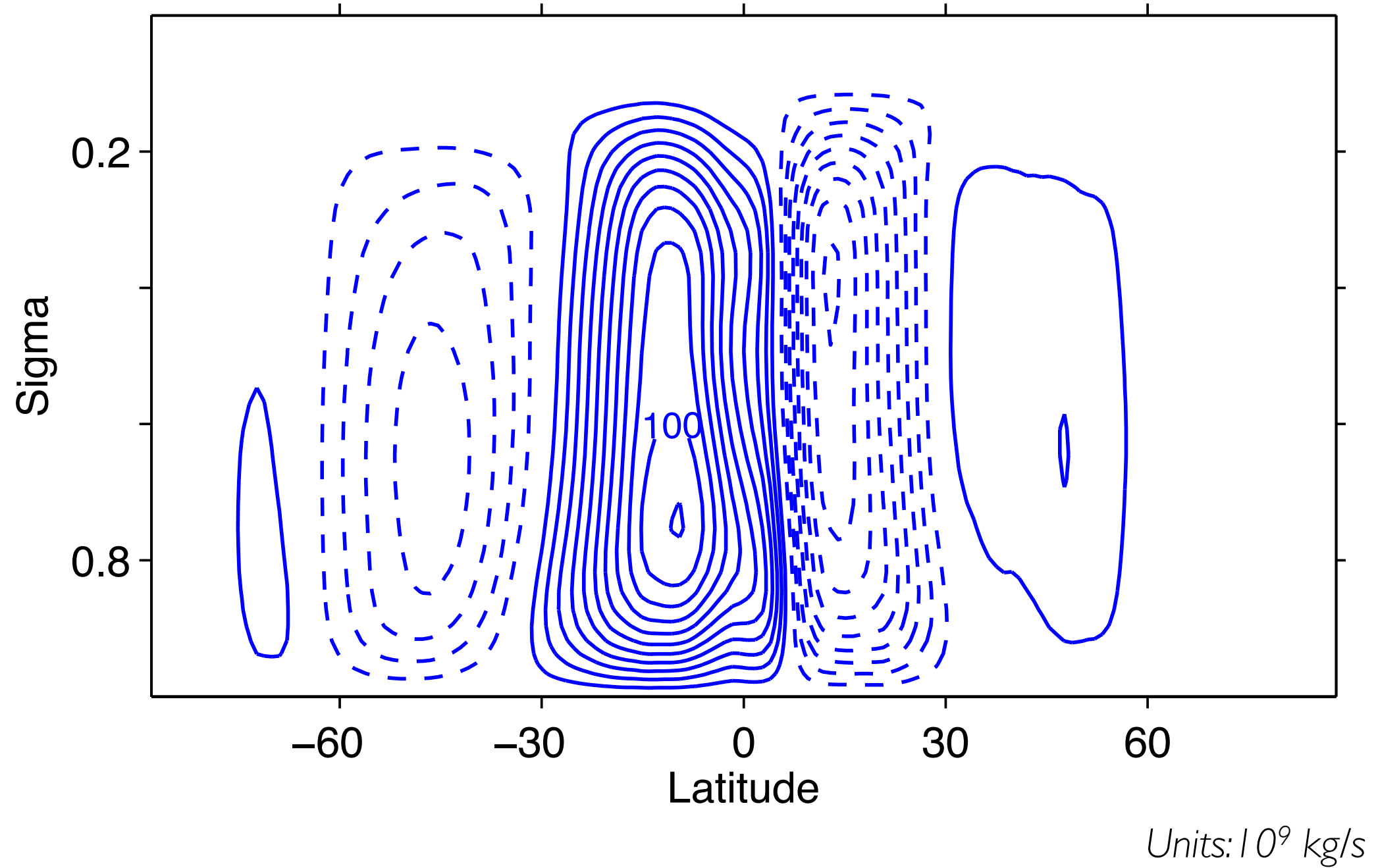
3) More cells, as well as angular momentum and heat transport by eddies (Jeffries 1926, Starr 1948, and many others)

4) Baroclinic instability (Eady 1950, Charney 1959)

Perhaps near the end of the 20th century we shall suddenly discover that we are beginning the fifth step.

E. N. Lorenz, BAMS, Vol 64, 730-734, 1983

The general circulation: 1980-2001 (ERA40)



The general circulation: recent trends (1980-2005)

(Update to Lorenz epistemological theory)

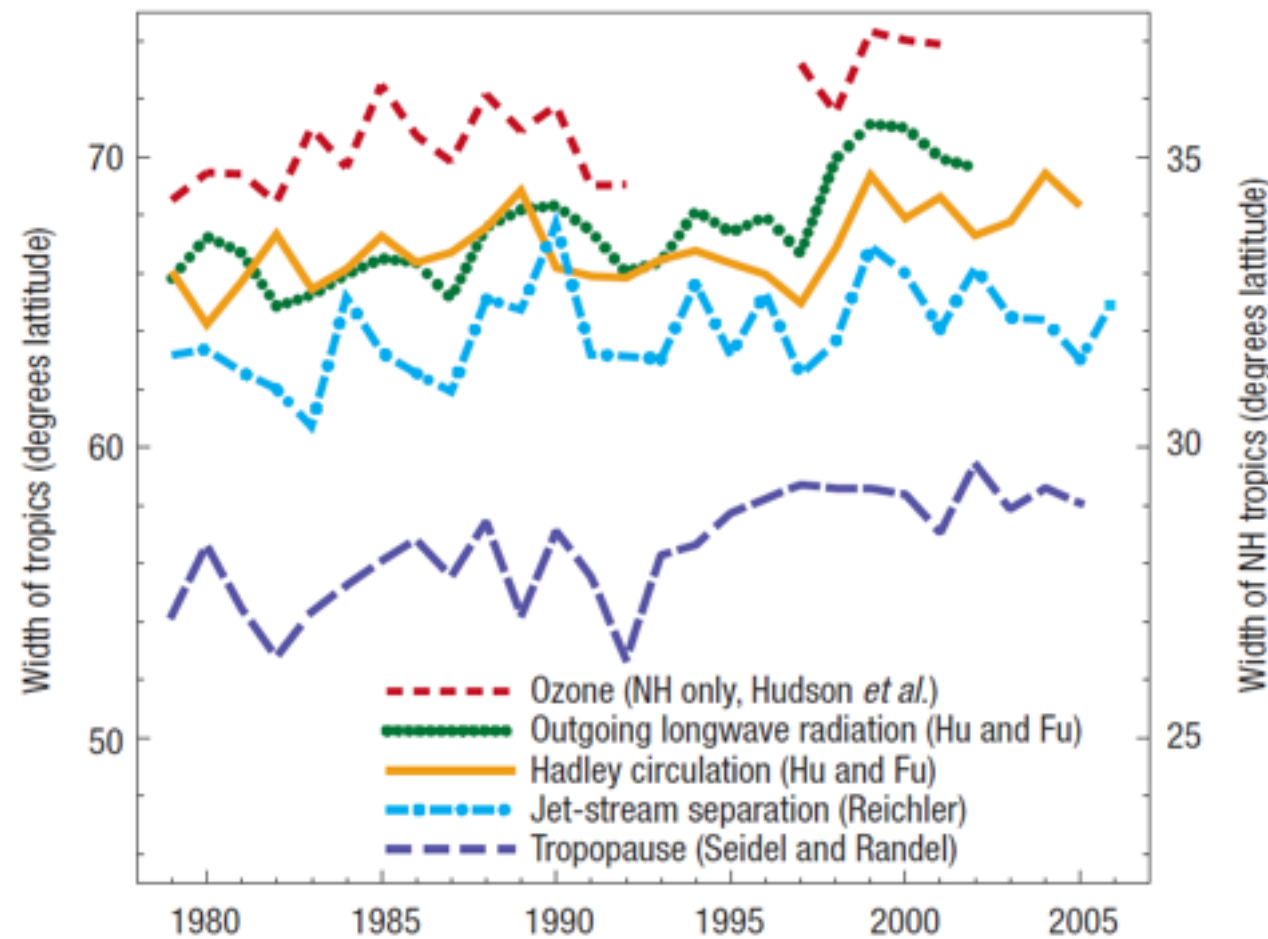


Figure 2 Changes in several estimates of the width of the tropical belt since 1979. These include: the width of the Hadley circulation, based on both outgoing longwave radiation and horizontal winds streamfunction¹⁰; the separation of the Northern and Southern Hemisphere subtropical jet-stream cores; the width of the region of frequent high tropopause levels⁸; and the width of the region with tropical column ozone levels (Northern Hemisphere only, right axis, ref. 6). Although each shows an increase since 1979, the rates vary from 2.0 to 4.8 degrees latitude per 25 years, with an even larger range when considering the entire spread of trend estimates in each individual study.